# Short and Medium Range Orders in Nearly Frictionless Diamond-Like Carbon

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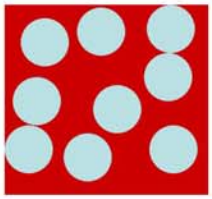
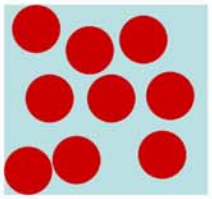
## Motivation.

Diamond-like carbon is an important technological material whose properties depend on ordering at both the short and medium range levels. Previous studies have concentrated on only the short range order, that is, quantifying the ratio of carbon $sp^3$ bonding to carbon $sp^2$ bonding. However, two diamond-like carbon films may have the same absolute ratios of $sp^3$ and $sp^2$ bonding, but very different medium range orders, giving rise to striking differences in their properties. This work correlates the short range ordering determined using Electron Energy Loss Spectroscopy (EELS) with the medium range order investigated using Fluctuation Electron Microscopy (FEM) in a set of diamond like carbon films with attractive friction properties.

These structures have similar absolute proportions of $sp^2$ and $sp^3$ short range ordering, but very ***different medium range orders***.



## Results.

| Film Name | Plasma Composition. | Coefficient of Friction | Hardness (GPa) | Hydrogen Content (at. %) |
|---|---|---|---|---|
| nfc2 | 50% $CH_4$:50%$H_2$ | 0.0040 | 16 | 39±3.9 |
| nfc6 | 25% $CH_4$:75%$H_2$ | **0.0010 !!** | 14.5 | 39±3.9 |
| nfc7 | 100% $CH_4$ | 0.0140 | 20 | 45 ±4.5 |
| nfc10 | 100% $C_2H_2$ | - | - | - |

Table 1: Summary of Nearly Frictionless Carbon Growth Parameters and Properties. ***nfc6 has the most desirable coefficient of friction***.

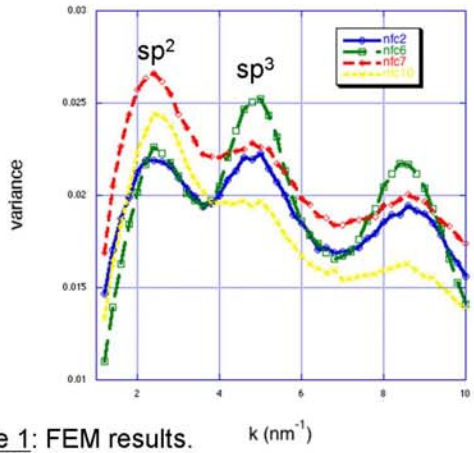
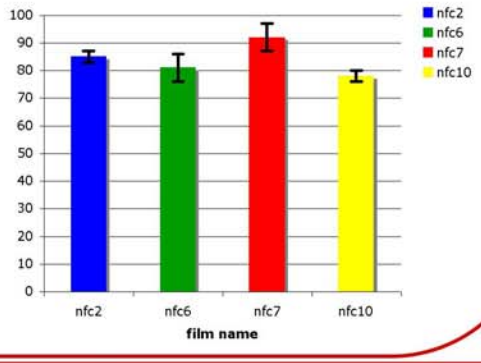



Figure 1: FEM results.
|peak 1| ∝ no. of graphitic clusters; |peak 2| ∝ no. of diamond-like clusters
While the degree of medium range order in the films comparable, ***nfc6 has the greater proportion of diamond-like clusters***.

Figure 2: EELS results.
For films made with a percentage of methane in the plasma the absolute percentage of $sp^2$ bonding in the films decreases with increasing hydrogen content in the plasma. This mirrors the FEM result. The trend seems to be inverted in the case of nfc10 which was grown in an acetylene atmosphere.




## Major Achievement.

Increasing the amount of hydrogen in the plasma during growth increases the absolute proportion of $sp^3$ bonding in the films and concomitantly, the number of $sp^3$ bonded clusters, enhancing the friction properties. Growth conditions can now be optimised for a low coefficient of friction.

## Future Directions.

These measurements were performed on the bulk of the films, whereas the friction properties may depend on the structure of a thin volume at the surface. Future experiments plan to concentrate on the ***homogeneity*** of the films. ***Isotropy*** of the amorphous films may also be investigated with high angular resolution EELS.

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